A Thematic Climate Data Record (TCDR) of Atmospheric Temperature Derived from Satellite Microwave Sounding Instruments Using 1D-Var MIRS

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1. Introduction

This study aims at directly deriving the atmospheric temperature at different pressure levels from all four MSU and MSU-like AMSU channels so that the climatology of the atmospheric temperature at specific pressure levels could be deduced globally . Specifically, the one-dimensional variational (1D-Var) Microwave Integrated Retrieval System (MIRS), which was originally designed for day-to-day numerical weather prediction (NWP) applications (Liu and Weng, 2005; Boukabara et al., 2011), is modified and a preliminary global climate data record (CDR) of atmospheric temperature is deduced.

2. MSU/AMSU Brightness Temperature Datasets

Merging multi-year satellite data from different MSU instruments requires careful adjustments of the observations to account for drifts caused by orbital decay and changes in local observing time, and determination of inter-satellite offsets and errors caused by changes in the temperature of the calibration sources. NOAA/STAR has recently released its level-1c inter-calibrated 30+year (1979-2011) MSU/AMSU observations (Zou et al., 2011). The instrument non-linearity is updated using simultaneous nadir overpassing (SNO) data. Diurnal-drift errors, incident angle errors, warm target temperature correction, and residual inter-satellite biases are accounted for. This dataset is used as input for the 1D-Var temperature retrieval of this study.

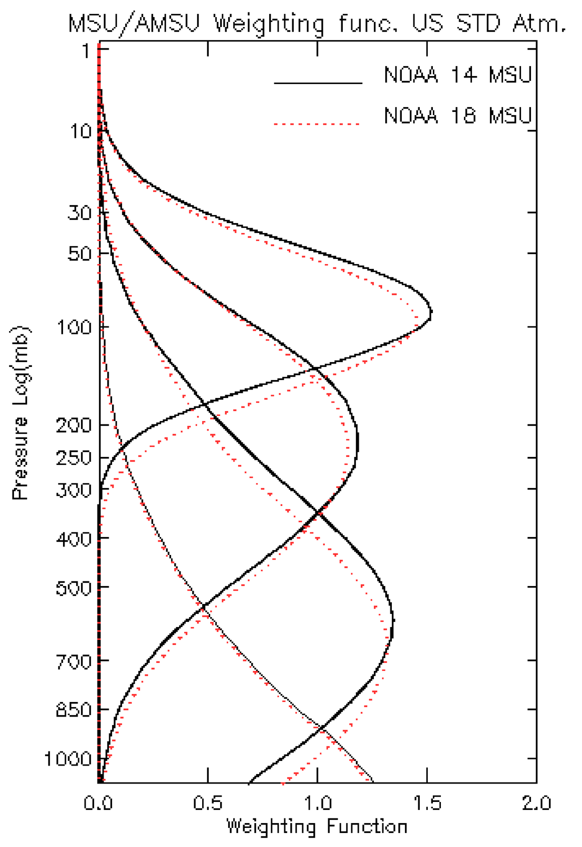


Fig. 1: Weighting functions of MSU channels 1-4 (solid) and AMSU-A channels 3, 5, 7, and 9 (dash) for the US standard atmosphere.

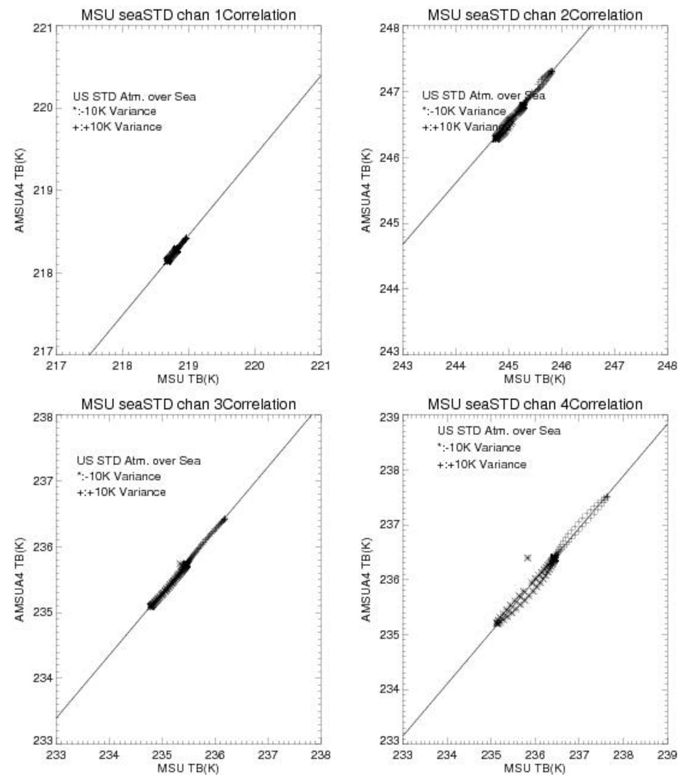


Fig.2 Scattering BT distribution of MSU and AMSU four corresponded channels which were estimated by CRTM. It shows linear correlation.

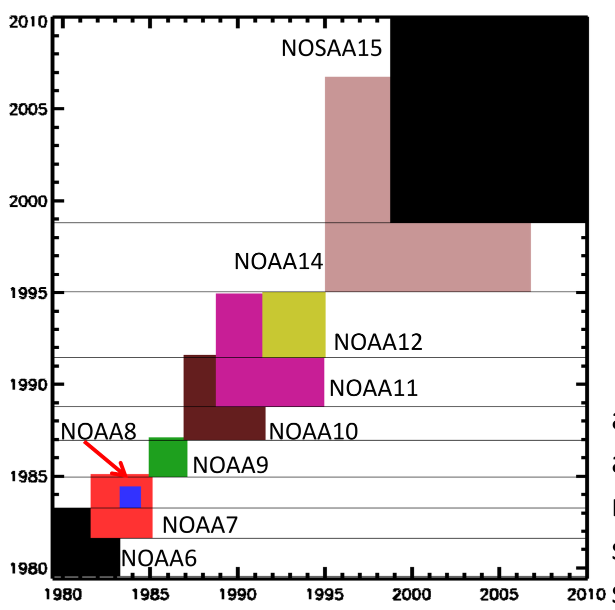


Fig. 3 MSU on board NOAA's earlier eight polar-orbiting. satellites (from NOAA-6 to NOAA-14) and AMSU-A on NOAA-15. Those are the satellite series of SNO data.

3. The 1D-Var Approach

assuming a clear-sky condition for CRTM simulation and the other cloudy conditions. The largest iteration numbers in the two sequences are set to two and seven, respectively. The minimization procedure is stopped if

$$\varepsilon \equiv \sum_{ich=1}^{4} \frac{(y_{ich}^{obs} - y^{(k)})^2}{(NE\Delta T)^2} < 1$$

The value of $(x)^k$ satisfying the above convergence criteria is taken as x* (e. g., the final 1D-Var retrieval product). In other words, the final 1D-Var solution (x*) represents an atmospheric state from which the CRTM-simulated brightness temperatures compare favorably with satellite measurements.

A schematic illustration of the 1D-Var is shown in Fig. 4

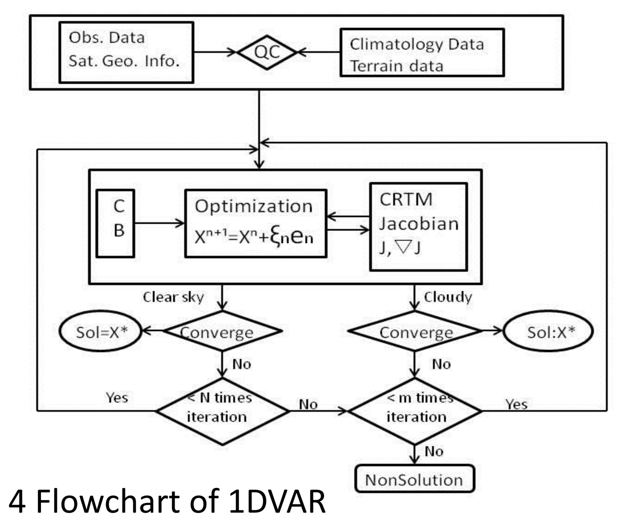


Fig. 4 Flowchart of 1DVAR

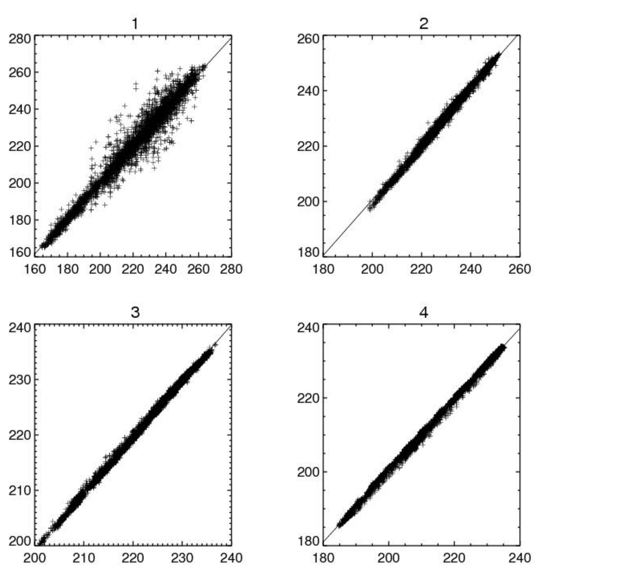


Fig . 5 The brightness temperature correlations between NOAA-14 MSU channels and the corresponding NOAA-15 AMSUA subset channels for SNO data in 2002. The total number of data count is 5166. Collocation criteria are Distance of Spatial < 100km. 2) Distance of Temporal < 100Sec.

3.2 Sensitivity Accessment

A total of four twin experiments is firstly carried out to examine the sensitivity of 1D-Var temperature retrievals to water vapor and sea-surface temperature (SST) variables. Using twin experiments to assess the impacts of SST and water vapor on temperature retrievals are convenient since the truth atmospheric profiles are known. Figure 5 presents the global root-mean-square error (RMSE) and the difference of RMSE between the analysis and the first guess of temperature retrievals from these four experiments compared with the truth. As shown in Fig. 4, an inclusion of water vapor and SST in the state control variable can improve the temperature retrievals throughout the atmosphere. Fixing SST has a negligible impact on the temperature retrieval, especially below 400 hPa.

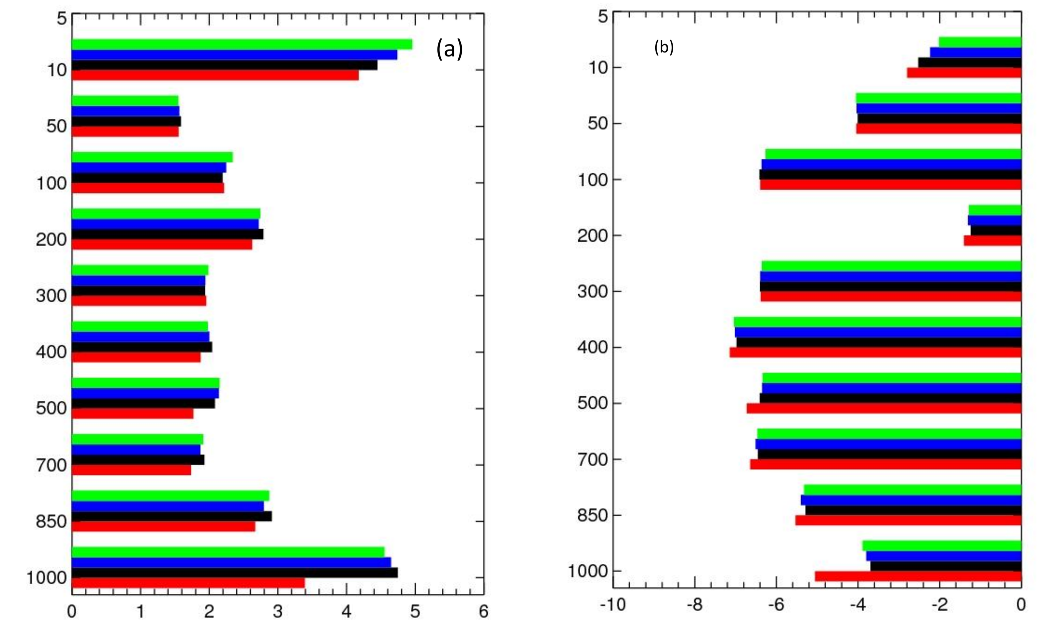
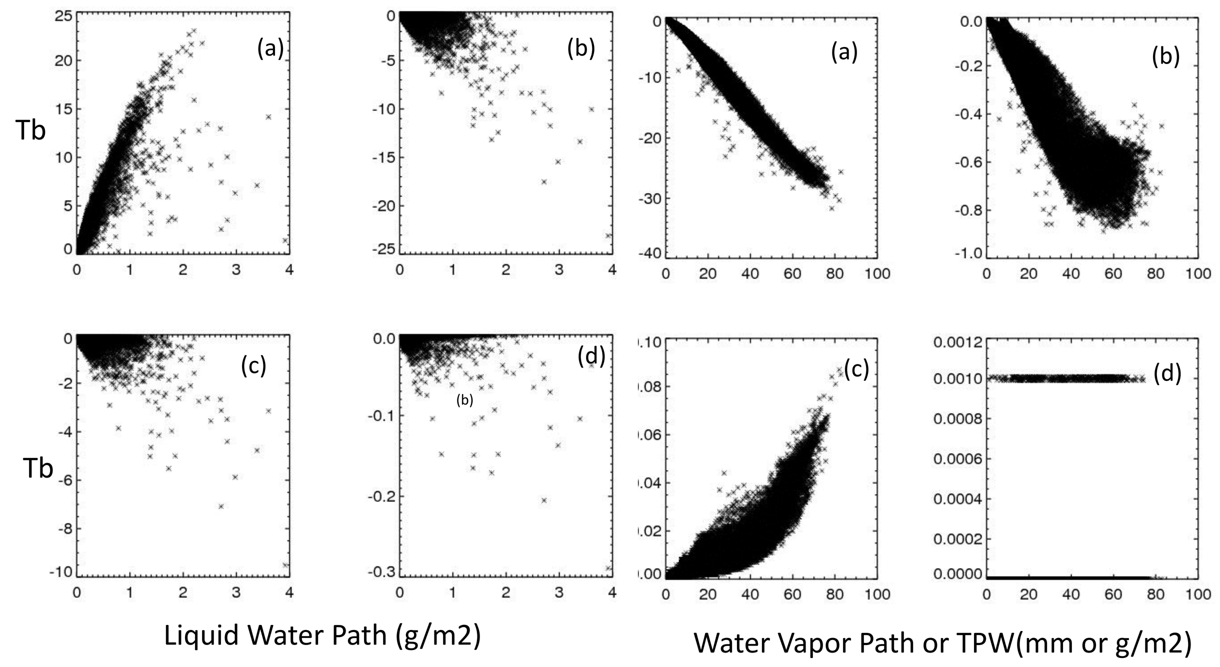


Fig. 6 RMSE of temperature retrievals derived from simulated AMSU-A channels 3, 5, 7 and 9. From four 1D-Var sensitivity-text experiments: EXP1 (red): both SST and water vapor serving as 1D-Var control variables; EXP2 (black): SST is fixed; EXP3 (blue): water vapor is fixed; and as 1D-Var control variables; EXP2 (black): SST is fixed; EXP3 (blue): water vapor is fixed; and RMSE of Obs. minus First Guess.



4. Real-Data Assimilation Results

4.1 Data Description

The MSU and AMSU dataset available from June 1979 to December 2009 were assimilated for obtaining microwave temperature retrieval. MSU data are corrected to AMSUA channels by regression coefficient in which differences between MSU and AMSU are considered.

4.2 Cloud Detection

A cloud detection algorithm similar to that in Weng and Grody (1993) is developed. the LWP can be estimated from AMSU channels 3 and 5. An LWP value greater than 0.5 g m^{-2} indicates the presence of liquid water clouds within the satellite field of view. The cloud detection is implemented by removing all data points with estimated LWP greater than this value.

4.3 Convergence

1DVAR Convergence has been checked by Model simulated data on Aug. 26. 2011.

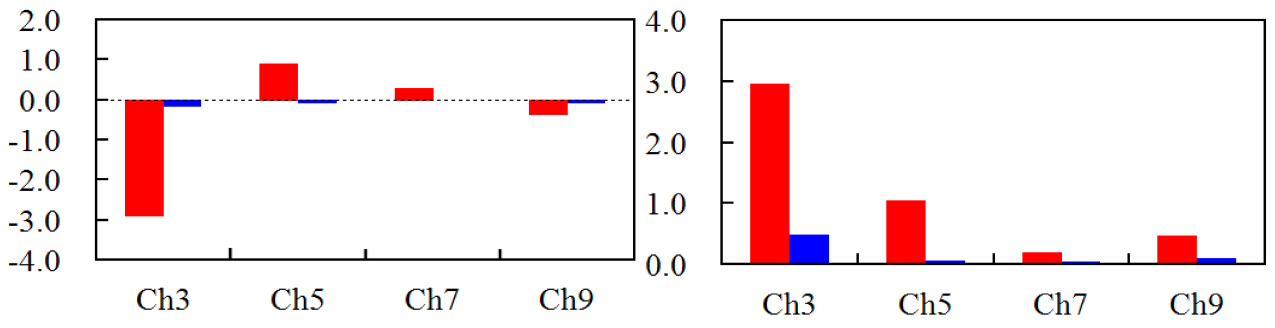


Fig. 8: (a) Mean and (b) RMS differences of brightness temperatures between observations and model simulations from initial guess (O-I, unit: 10K) and 1D-Var analysis (O-A, unit: K) on August 28, 2011.

5. Results

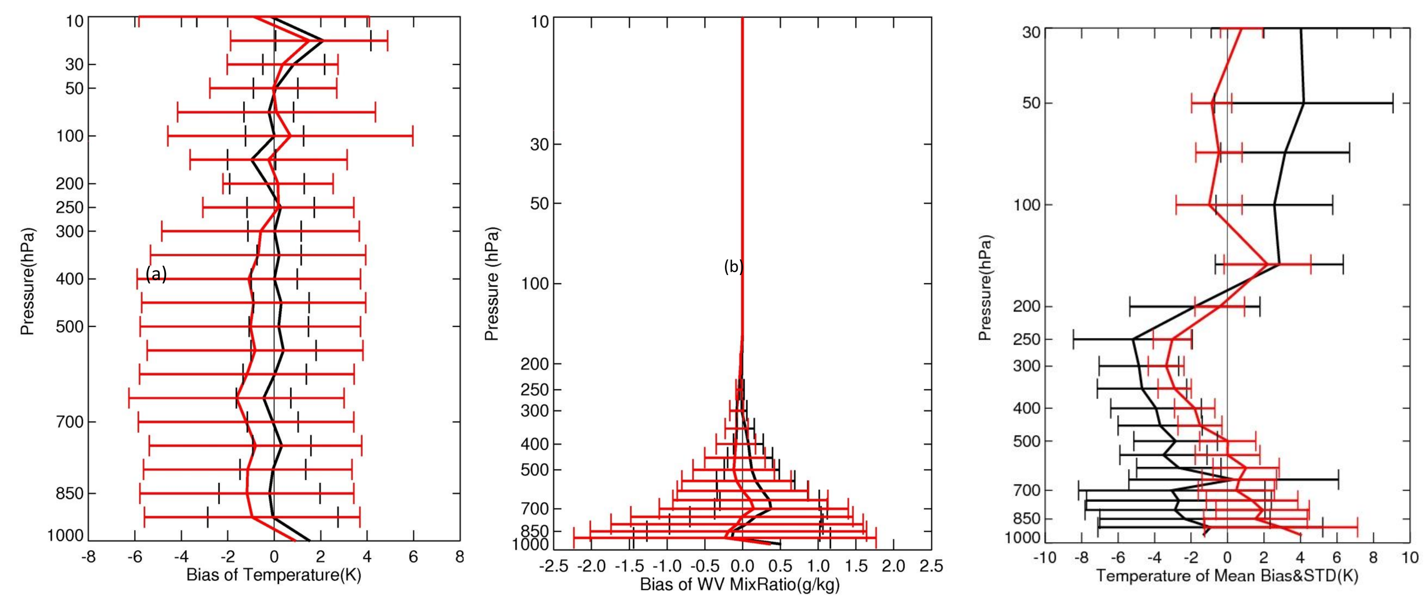


Fig. 9 Mean error (solid) and RMS errors (horizontal bar) of atmospheric temperature profiles from the initial guess (red) and the 1D-Var retrievals (black) verified with COSMIC GPS RO data during June 1-10 in 2008-2011. Collocation criteria in time and space are set to be one hour and 50 km, respectively. (a) Only AMSU-A channels 3, 5, 7 and 9 are assimilated. (b)) is retrieved water vapor by AMSU four channels. (c) Point to point comparison between N15 AMSUA and N14 MSU and COSMIC on Sep. 2006

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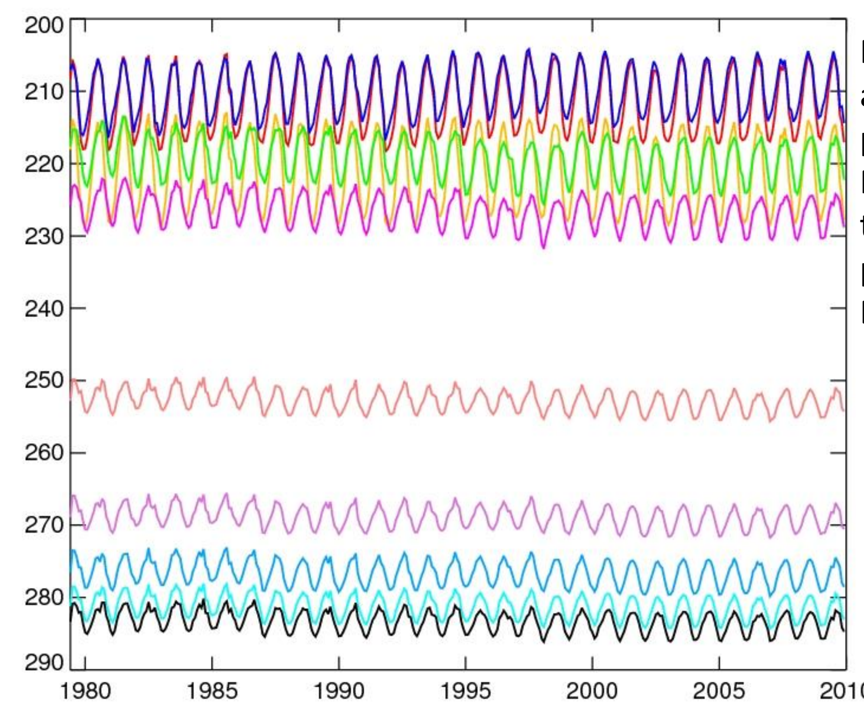
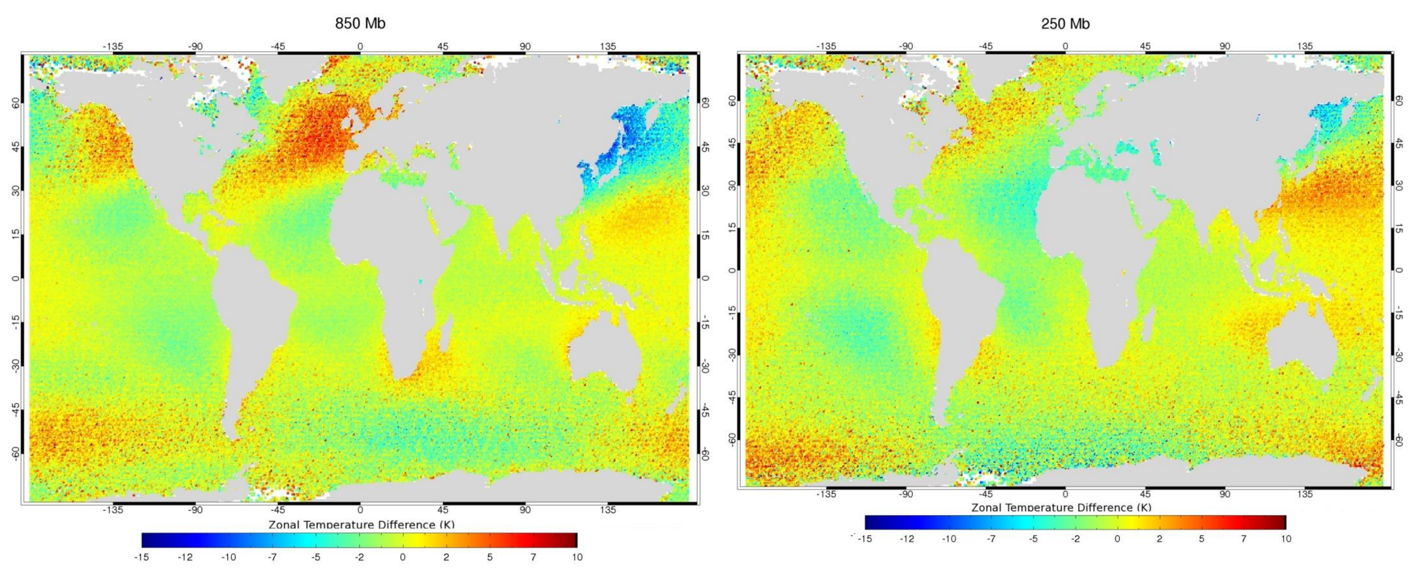


Fig. 10: Monthly and global mean atmospheric temperatures at ten pressure levels retrieved from MSU/AMSU-A brightness temperatures during the 30-year periods from June 1979 to December 2009.



Pressure(hPa)	This Research	Dr . ChengZhi,Zou	Reference Level
30	0.052		
50	0.038	0.028	TLS
60	0.003		
200	0.012		
250	0.060	0.045	TUT
750	0.038	0.028	TMT
800	0.021		

Table.2 Annual Temperature Anomaly Trend compared with Dr. ChengZhi Zou.

6. Summary and Conclusions

In this study, a 1D-Var method is used for detecting the global warming/cooling trends through a direct assimilation of global oceanic brightness temperatures observed by MSU and AMSU-A on board the NOAA polar-orbiting satellites over the time period from June 1978 to August 2010.